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The influence of body mass index on injury pattern in polytrauma: thorax as the main source of complications

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Abstract

Background: Obesity is a growing problem in industrial nations. The aim of this study was to determine the relationship between the body mass index (BMI) and the pattern of injury after polytrauma.

Methods: This retrospective study included 651 patients with an injury severity score (ISS) ≥16 and aged ≥16 years who were subdivided into three groups: BMI < 25 kg/m^2, BMI 25–30 kg/m^2, and BMI > 30 kg/m^2. The Abbreviated Injury Scale (AIS) was used to quantify the injuries in the different anatomical regions. The Murray score was assessed at admission and at its maximum during hospitalization to evaluate pulmonary problems. Data are presented as means ± standard errors of the means. One way analysis of variance, χ^2 test and Kruskal-Wallis test were used for the analyses and the significance level was set at $p < 0.05$.

Results: The AIS of the thorax was 3.2 ± 0.1 in the BMI < 25 kg/m^2 group, 3.3 ± 0.1 in the BMI 25–30 kg/m^2 group, and 2.8 ± 0.2 in the BMI > 30 kg/m^2 group; $p < 0.05$. The Murray score at admission increased significantly with increasing BMI (0.8 ± 0.8 for BMI < 25 kg/m^2, 0.9 ± 0.9 for BMI 25–30 kg/m^2, and 1.0 ± 0.8 for 0BMI > 30 kg/m^2; $p < 0.05$) as was the maximum Murray score during hospitalization (1.2 ± 0.9 for BMI < 25 kg/m^2, 1.6 ± 1.0 for BMI 25–30 kg/m^2, and 1.5 ± 0.9 for BMI > 30 kg/m^2; $p < 0.001$). The number of ventilator days was also elevated significantly with increasing BMI (5.9 ± 0.4 for BMI < 25 kg/m^2, 7.7 ± 0.8 for BMI 25–30 kg/m^2, and 7.9 ± 1.6 for BMI > 30 kg/m^2; $p < 0.05$).

Conclusion: Overweight and obesity lead to a higher incidence of thoracic trauma in a polytrauma situation and may additionally handicap ventilation in an obstructive manner.

Keywords: BMI, polytrauma, abbreviated injury scale, murray score, SOFA score

Introduction

Inconsistent findings have been reported for the association between body mass index (BMI) and polytrauma [1,2]. BMI is an anthropometric index defining the weight-to-height relationship, and is expressed as the weight of the individual in kilograms divided by the square of his/her height in meters (kg/m^2). Individuals with normal weight have BMIs between 18.5 and 24.9 kg/m^2; overweight is defined as BMI ≥ 25 kg/m^2 and obesity as BMI ≥ 30 kg/m^2. BMI values are age and sex independent [3], and obesity is known to be one of the most significant risk factors for diseases such as cancer, heart disease, and diabetes mellitus in Western countries [4].The association between chronic diseases and obesity is clear, but the impact of obesity on the pattern of injury after a polytrauma remains unclear [2]. Most studies about the association between BMI and polytrauma have focused on whether obesity and its comorbidities predict the mortality rate in obese patients with polytrauma. Recently, analysis of computational models of injury severity and injury pattern revealed a highly significant association of thoracic and pelvic injuries with increasing BMI [5]. However, this analysis was computed using crash-test dummies in simulated motor vehicle crashes as a standardized trauma mechanism, while some body fat may have a cushioning effect and may protect the abdominal organs from blunt trauma [6]. Older studies have shown that obese patients tend to acquire rib fractures after a trauma, which also highlights the thorax as the weak point in obese people who suffer motor vehicle accidents [7]. It is unknown whether body-fat content plays a role in everyday traumaor may lead to more accidents. In this study scoring systems were used to determine the pulmonary impairment and the overall organ impairment of the patient after a polytrauma. The Murray score depicts explicitly the pulmonary function and the SOFA score mirrors the overall organic function of the polytrauma patient [8,9]. The aim of this study was to analyze the association of BMI with the injury pattern and outcomes under polytrauma conditions and to determine whether thoracic injuries should be in the center of interest in overweight and obese patient's after polytrauma indicated by the Abbreviated Injury Scale (AIS), as well asto assess the systemic influence of thoracic problems after a polytrauma by the Murray and SOFA scores.

Patients and methods

Patients

Six hundred fifty-one patients with polytrauma admitted to the emergency room of the University Hospital of Zürich

Table 1. Characteristics of the patient cohort at admission.

Characteristics	Total	BMI 18.5–25 kg/m²	BMI 25–30 kg/m²	BMI > 30 kg/m²	p - value	Kolmogorov-Smirnov	Bonferroni BMI 18.5-25 vs. BMI 25-30	Bonferroni BMI 18.5-25 vs. BMI > 30	Bonferroni BMI 25-30 BMI > 30
Patients [N]	651	378	224	49	-	-	-	-	-
Age [years]	42.9 ± 0.75	42.9 ± 1.0	43.4 ± 1.3	44.3 ± 2.4	0.715*	0.001	ns.	ns.	ns.
Sex male/female [N]	495/156	264/114	191/33	40/9	< 0.002†		< 0.001	ns.	ns.
BMI [kg/m²]	25.0 ± 0.1	22.7 ± 0.1	27.0 ± 0.1	32.7 ± 0.6	-	-	-	-	-
ISS	28.4 ± 0.5	28.0 ± 0.6	29.7 ± 0.9	25.0 ± 1.3	0.036*	0.000	ns..	ns.	ns.
NISS	38.3 ± 0.6	37.6 ± 0.8	39.7 ± 1.1	37.2 ± 2.0	0.248*	0.000	ns.	ns.	ns.
APACHE II	14.6 ± 0.3	13.9 ± 0.5	15.8 ± 0.6	13.6 ± 1.1	0.026*	0.000	ns.	ns.	ns.
Schock	1.5 ± 0.0	1.5 ± 0.0	1.5 ± 0.1	1.5 ± 0.1	0.909*	0.000	ns.	ns.	ns.
GCS	9.1 ± 0.2	9.3 ± 0.3	8.6 ± 0.4	10.4 ± 0.8	0.085*	0.000	ns.	ns.	ns.
MAP [mmHg]	90.7 ± 1.4	89.5 ± 1.1	93.2 ± 3.4	88.8 ± 2.5	0.427*	0.000	ns.	ns.	ns.
Hemoglobin [g/L]	11.0 ± 0.1	11.1 ± 0.2	11.0 ± 0.2	11.0 ± 0.5	0.760‡	0.217	ns.	ns.	ns.
Base excess [mmol/L]	−2.9 ± 0.3	−2.4 ± 0.4	−3.1 ± 0.7	−4.1 ± 0.7	0.129‡	0.168	ns.	ns.	ns.
Lactate [mmol/L]	3.0 ± 0.1	2.9 ± 0.1	3.2 ± 0.2	2.8 ± 0.2	0.438*	0.000	ns.	ns.	ns.
pH	7.3 ± 0.0	7.3 ± 0.0	7.3 ± 0.0	7.3 ± 0.0	0.774*	0.000	ns.	ns.	ns.
Prothrombin time [%]	78.6 ± 1.0	77.9 ± 1.3	79.1 ± 1.6	81.2 ± 3.4	0.073*	0.000	ns.	ns.	ns.
Platelets [10³/μL]	196.1 ± 3.7	196.2 ± 5.1	192.1 ± 6.2	214.6 ± 13.1	0.308*	0.015	ns.	ns.	ns.

in the period 1996–2008 were included in this study. The inclusion criteria were: age ≥16 years and admission within 24 h of incurring polytrauma, defined as an injury severity score (ISS) ≥16. The patients were treated in the intensive care unit (ICU) and underwent damage control surgery where necessary. The study population was subdivided into three groups (**Table 1**): BMI < 25 kg/m², BMI 25–30 kg/m², and BMI > 30 kg/m². The minimum acceptable BMI was 18.5 kg/m². All patient data were collected retrospectively from patient records with the approval of the local institutional review board (IRB) according to the University of Zürich IRB guidelines and the World Medical Association Declaration of Helsinki, and the study was conducted according to the guidelines for good clinical practice (*"RetrospektiveAnalysen in der ChirurgischenIntensivmedizin"* Nr. StV. 01-2008).

Diagnostic protocol

All hemodynamically stable patients admitted to the trauma bay underwent an immediate whole-body computed tomography (CT) scan. Unstable patients underwent resuscitative procedures according to the Advanced Trauma Life Support® (ATLS®) standards with a subsequent whole-body CT scan.

Primary care

The treatment of all admitted patients was according to the ATLS® guidelines and a previously assessed trauma management protocol after appropriate indications were identified [**10**,**11**]. Briefly, after airway intubation, ventilation, and cardiovascular management, lifesaving surgery was performed with decompression of the body cavities, control of any hemorrhage and the identification of any contaminated tissues. These initial surgical interventions were followed by the stabilization of major fractures and the radical debridement of necrotic tissues. Cefazolin was used as the perioperative antibiotic. In all of these patients, enteral nutrition was established within 24 h of trauma to prevent spontaneous transmigration of the enteric microbial flora and peritoneal contamination.

Scoring systems

The Murray and SOFA scores were used to evaluate the physiological impairment of the patient [**8**,**9**]. The Murray score was taken to estimate ventilatory impairment in polytrauma patients focusing as well on the gas exchange as on the functionality of the organ, and the SOFA score was used to assess the overall organ dysfunction in polytrauma patients. The ISS and the New Injury Severity Scale (NISS) were used to define the severity of trauma [**12**,**13**]. The Acute Physiology and Chronic Health Evaluation (APACHE II) score wasused to evaluate the overall physiological impairment of the patient at admission [**14**]. The AIS, version 2005, was used to describe injuries in specific anatomical regions.

Laboratory parameters

Lactate, pH, and hematocrit were measured at regular intervals with a blood gas analyzer (ABL 800 Flex; Radiometer GmbH, Thalwil, Switzerland). Platelets were measured by flow cytometry (FACS-Calibur; Becton Dickinson, Allschwil, Switzerland). The prothrombin time was measured by a standard method described previously [**15**].

Statistical analysis

Data are presented as the means ± standard errors of the

Table 2. Abbreviated Injury Scale.

Anatomical region	Total	BMI 18.5–25 kg/m²	BMI 25–30 kg/m²	BMI > 30 kg/m²	p- value	Kolmogorov-Smirnov	Bonferroni BMI 18.5-25 vs. BMI 25-30	Bonferroni BMI 18.5-25 vs. BMI > 30	Bonferroni BMI 25-30 BMI > 30	R^2
AIS head	3.6 ± 0.1	3.6 ± 0.1	3.7 ± 0.1	3.3 ± 0.3	0.474*	0.000	ns.	ns.	ns.	0.001
AIS face	2.1 ± 0.1	2.2 ± 0.1	2.1 ± 0.1	1.6 ± 0.2	0.114*	0.000	ns.	ns.	ns.	0.017
AIS thorax	3.2 ± 0.0	3.2 ± 0.1	3.3 ± 0.1	2.8 ± 0.2	0.043*	0.000	ns.	ns.	0.039	0.002
AIS abdomen	4.0 ± 0.1	4.0 ± 0.1	4.0 ± 0.1	3.9 ± 0.3	0.622*	0.000	ns.	ns.	ns.	0.000
AIS spine	3.0 ± 0.1	3.1 ± 0.1	3.0 ± 0.2	2.3 ± 0.2	0.093*	0.000	ns.	ns.	ns.	0.024
AIS extremities	2.8 ± 0.0	2.8 ± 0.1	2.7 ± 0.1	3.0 ± 0.2	0.176*	0.000	ns.	ns.	ns.	0.000
AIS pelvis	2.8 ± 0.0	2.7 ± 0.1	2.9 ± 0.1	3.0 ± 0.1	0.196*	0.000	ns.	ns.	ns.	0.021
AIS skin	1.6 ± 0.1	1.5 ± 0.1	1.8 ± 0.1	1.4 ± 0.3	0.266*	0.000	ns.	ns.	ns.	0.005

Table 3. Laboratory parameters at admission and after 24 h. Data are given as means ± SEM.

Value	Total	BMI 18.5–25 kg/m²	BMI 25–30 kg/m²	BMI >30 kg/m²	p-value	Kolmogorov-Smirnov	Bonferroni BMI 18.5-25 vs. BMI 25-30	Bonferroni BMI 18.5-25 vs. BMI > 30	Bonferroni BMI 25-30 BMI > 30
BE at admission [mmol/L]	−2.85 ± 0.3	−2.4 ± 0.4	−3.2 ± 0.7	−4.2 ± 0.7	0.129†	0.168	ns.	ns.	ns.
BE after 24 h [mmol/L]	1.0 ± 0.3	1.62 ± 0.3	0.0 ± 0.5	1.1 ± 0.5	0.013*	0.028	0.010	ns.	ns.
Lactate at admission [mmol/L]	3.0 ± 0.1	2.9 ± 0.1	3.2 ± 0.2	2.8 ± 0.2	0.438*	0.000	ns.	ns.	ns.
Lactate after 24 h [mmol/L]	1.6 ± 0.1	1.4 ± 0.1	1.8 ± 0.1	1.7 ± 0.2	0.015*	0.000	0.015	ns.	ns.
pH at admission	7.29 ± 0.02	7.28 ± 0.03	7.30 ± 0.01	7.31 ± 0.01	0.774*	0.000	ns.	ns.	ns.
pH after 24 h	7.40 ± 0.00	7.41 ± 0.00	7.38 ± 0.01	7.40 ± 0.01	0.058†	0.105	ns.	ns.	ns.
Prothrombin time atadmission [%]	78.6 ± 0.9	77.9 ± 1.3	79.1 ± 1.6	81.2 ± 3.4	0.601*	0.000	ns.	ns.	ns.
Prothrombin time after 24 h [%]	88.5 ± 0.6	87.6 ± 0.8	89.9 ± 1.0	88.9 ± 2.3	0.201*	0.000	ns.	ns.	ns.
Platelets at admission [10^3/mL]	196.1 ± 3.7	196.2 ± 5.0	192.1 ± 6.2	214.6 ± 13.1	0.268†	0.090	ns.	ns.	ns.
Platelets after 24 h [10^3/mL]	142.4 ± 3.3	141.4 ± 4.7	142.6 ± 5.2	148.2 ± 11.4	0.869*	0.001	ns.	ns.	ns.
Hemoglobin at admission [g/L]	11.0 ± 0.1	11.1 ± 0.2	11.0 ± 0.2	10.9 ± 0.5	0.706†	0.217	ns.	ns.	ns.
Hemoglobin after 24 h [g/L]	9.7 ± 0.1	9.8 ± 0.1	9.6 ± 0.2	9.9 ± 0.5	0.628†	0.282	ns.	ns.	ns.

means (SEM) for continuous variables and as percentages for categorical variables. Kolmogorov-Smirnov test was used for normality testing, if $p < 0.05$ the data were considered as normally distributed. The data for the BMI groups were compared using the χ^2 test for categorical data and one wayanalysisof variance (ANOVA) for continuous data. Bonferroni correctionused as a *post hoc* analysisto reduce the witness of a rare event in multiple hypotheses. For not normally distributed data, the Kruskal-Wallis test was used. $p < 0.05$ was considered significant. The data were analyzed using SPSS software (version 20.0; IBM, Armonk, NY, USA).

Results

Patient sample

All BMI data given below are reported in kg/m², but for simplicity of presentation, the units are not included. A total of 651 patients met the inclusion criteria: 378 were of normal weight with a BMI 18.5–25, 224 were overweight, with a BMI 25–30 and 49 were obese with a BMI > 30. Of these patients, 495 were men and 156 were women, with significantly more men in all three groups ($p = 0.002$; **Table 1**). The overall mean BMI was 25.0 ± 0.1. The mean age was 42.9 ± 0.75 years and did not significantly differ between BMI groups. Only 14 patients (four men and 10 women) met the criteria for being underweight (BMI < 18.5) and were excluded from the study. All patients admitted to the trauma bay who met the inclusion criteria were included in the study.

Injury patterns

The analysis of the injury patterns according to the AIS revealed significant differences between the BMI groups only in the thorax region, with scores of 3.2 ± 0.1 in the BMI 18.5–25 group, 3.3 ± 0.1 in the BMI 25–30 group, and 2.8 ± 0.2 in the BMI > 30 group ($p = 0.043$; **Table 2**). In this patient sample, ISS and APACHE II values differed between groups, but not NISS ($p = 0.036$ and $p = 0.026$, **Table 1**).

Laboratory analysis

There were significant differences between BMI groups in lactate ($p = 0.015$) 24 h after admission, but these values were still within the normal range (**Table 3**). Base excess (BE), prothrombin time, platelet values and hemoglobin did not differ significantly between BMI groups at any time point (**Table 3**).

Outcome measurement

Overall, 17.5% of all patients included in the study died: 15.1% of the BMI 18.5–25 group; 21.0% of the BMI 25–30 group; and

Table 4. Outcome values for the entire patient cohort, showing Murray and SOFA scores at admission, their maximal values (max.) during hospitalization and the days after admission at which the maximal values were reached (day max.). Data are given as means ± SEM, *χ².

Outcome	Total	BMI 18.5–25 kg/m²	BMI 25–30 kg/m²	BMI >30 kg/m²	p- value	Kolmogorov-Smirnov	Bonferroni BMI 18.5-25 vs. BMI 25-30	Bonferroni BMI 18.5-25 vs. BMI > 30	Bonferroni BMI 25-30 vs. BMI > 30
Death [N, (%)]	114 (17.5%)	57 (15.1%)	47 (21.0%)	10 (20.4%)	0.181 *	0.000	-	-	-
Day of death [d]	4.7 ± 1.3	4.5 ± 1.8	5.7 ± 2.3	2.7 ± 1.7	0.765†	0.000	ns.	ns.	ns.
Hospitalization [d]	25.8 ± 1.1	24.1 ± 1.2	27.7 ± 2.5	29.2 ± 3.6	0.228†	0.000	ns.	ns.	ns.
Intensive care stay [d]	11.6 ± 0.5	10.7 ± 0.6	12.6 ± 0.9	13.1 ± 2.2	0.164†	0.000	ns.	ns.	ns.
Ventilation [d]	6.7 ± 0.4	5.9 ± 0.4	7.7 ± 0.8	7.9 ± 1.6	0.044†	0.000	ns.	ns.	ns.
Murray score (admission)	0.9 ± 0.0	0.8 ± 0.0	0.9 ± 0.1	1.0 ± 0.1	0.043†	0.000	ns.	ns.	ns.
Murray score (max.)	1.4 ± 0.0	1.2 ± 0.0	1.6 ± 0.1	1.5 ± 0.1	0.000†	0.000	0.000	ns.	ns.
Murray score (day max.) [n]	2.8 ± 0.2	2.6 ± 0.2	3.3 ± 0.3	3.0 ± 0.6	0.113†	0.000	ns.	ns.	ns.
SOFA (admission)	6.1 ± 0.2	5.9 ± 0.2	6.2 ± 0.3	6.5 ± 0.6	0.517†	0.000	ns.	ns.	ns.
SOFA (max.)	7.6 ± 0.2	7.1 ± 0.2	8.2 ± 0.3	7.9 ± 0.6	0.017†	0.000	0.018	ns.	ns.
SOFA (day max.) [n]	2.1 ± 0.1	1.9 ± 0.2	2.5 ± 0.3	1.9 ± 0.4	0.087†	0.000	ns.	ns.	ns.

20.4% of the BMI > 30 group ($p = 0.181$; **Table 4**). The number of days on the ventilator in ICU increased with increasing BMI: the average number of ventilator days for all patients was 6.7 ± 0.4 d, tendencially increasing according the BMI group (**Table 4**). Pulmonary assessment by the Murray score at admission showed increasing tendencies according the BMI groups (**Table 4**). The overall maximal Murray score value reached 1.4 ± 0.9: 1.2 ± 0.9 for the BMI 18.5–25 group; 1.6 ± 1.0 for the BMI 25–30 group; and 1.5 ± 0.9 for the BMI > 30 group ($p < 0.001$; **Table 4**). There were no significant differences between the groups in the SOFA score at admission; however, the maximal value was significantly elevated in the overweight group. The overall maximal value was 7.6 ± 4.5: 7.1 ± 4.3 for the BMI 18.5–25 group; 8.2 ± 4.8 for the BMI 25–30 group; and 7.9 ± 4.5 for the BMI > 30 group (p=0.017; **Table 4**).

Discussion

This study was designed to evaluate the impact of BMI on the pattern of injury in patients with polytrauma. Understanding the main source of complications in overweight and obese polytrauma patients may play a pivotal role in their multidisciplinary treatment. In Western societies, the prevalence of obesity is a growing problem that appears to be altering current medical and surgical treatment strategies [16]. Overweight patients have significantly more comorbidities than normal weight patients and face more posttraumatic complications [17,18].

The overweight patient exhibits more non-muscle mass than the normal weight patient; this cannot be controlled during an accident resulting in a greater 'momentum effect' and leading to a higher deceleration [19]. The cushioning effect of fat might be a satisfactory explanation for fewer injuries in obese patients after blunt abdominal trauma, but this would not apply to the thoracic region [19]. Because of a higher kinetic energy during an accident, the overweight or obese patient sustains a higher impact than the normal weight patient, which leads to a higher incidence of thoracic injuries among these patients. However, in this study, the AIS for thorax was lowest in the obese group, so that above a certain BMI, a cushion effect must be postulated [19]. Measurements of pulmonary parameters reported as a Murray score at admission and at the maximum during hospitalization showed a significant increase with increasing BMI [10]. This problem may be explained not only by the trauma, but might also be related to body-fat content: overweight and obese patients may have obstructed breathing, formerly called *Pickwickian Syndrome*, which is reflected in the Murray score [20]. The low efficacy of respiration in overweight and obese patients leads to higher maximal values of the Murray score during hospitalization (**Table 4**). Interestingly, this impaired respiration significantly affects the BE, lactate and pH, as there were significant differences between BMI groups after the first 24 h (**Table 3**); however, these parameters were still within physiological ranges. It could be postulated that this is the product of renal compensation, but fluid treatment in the ICU is a more obvious cause. The number of ventilator days increased with increasing BMI: obese patients had significantly more ventilator days even though the AIS was lowest in the obese group. Again, it seems that it is the obstructive breathing of obese patients, not only the trauma itself, that is the primary reason why obese patients spent more time on a ventilator; weaning from the ventilator is always prolonged in patients with obstructive breathing disorders. The maximum SOFA score was also increased significantly in overweight and obese patients, but not the score at admission, which also reflects the respiratory problems of the overweight and obese patients.However, the compliance of the lung used in both scoring systems may mainly contribute to the significance of the maximal values of the SOFA score, on the one hand. On the other hand the just significant difference of the Murray score at admission may reflect only ventilator problems and not severe traumatic problems as reflected by the AIS for the thorax. In such early stages after a polytrauma there is no change in compliance of the lung or chest x-ray with respect to the obtained AIS of the thorax. Only the PEEP and oxygenation values are left to explain the differences of the Murray score at admission. This may be explained by the obstructive component of the fatty tissue as mentioned above, the *Pickwickian Syndrome* in some extent. Secondarily, probably caused by the decreased oxygenation the other organ parameters may change in an adverse manner leading to significant differences in the maximal values of the SOFA score. Whether the significantly elevated mortality of the overweight patients after suffering a polytrauma is founded in their respiratory difficulties or in other thoracic problems needs further investigation. The limitations of this study are determined by the study's retrospective character. The conclusions made here are interpretations of probabilities and no casualties. This study is strongly limited to Western Europe and cannot be transferred to other geographical and cultural regions.

Conclusion

In summary, this study showed that compared with normal weight patients, overweight patients have a higher incidence of thoracic trauma, but obese patients have a lower incidence of thoracic trauma, probably because of the cushioning effect of body fat [19]. However, excess fatty tissue leads to obstructed ventilation, resulting in higher Murray scores and higher numbers of ventilator daysand secondarily probably to increased SOFA score, probably by a decreased oxygen supply of the organs. The awareness of thoracic problems in overweight and obese polytrauma patients under ICU conditions may lead to an optimization of ventilator parameters that will probably improve their outcomes.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

Study design, statistical analysis, preparing of the Manuscript and collection of the data was performed by L. Mica. Acquisition of the data was performed by C. Keller, J. Vomela, M. Keel, O. Tretz and M. Plecko.

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